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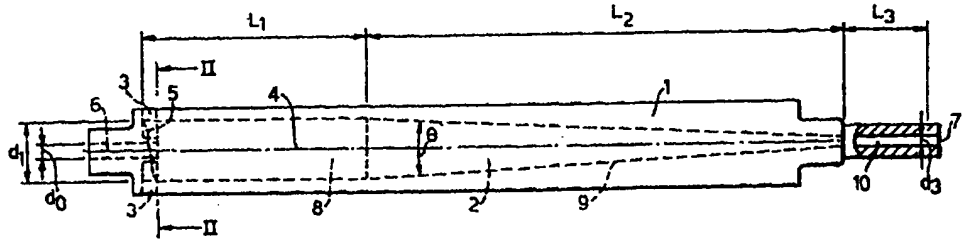

(57) Abstract

A dehydrating hydrocyclone having a cylindrical inlet portion (8) the length (l_1) of which is at least twice its diameter (d_1). The cylindrical portion leads into the tapered portion (9) the length (l_2) of which is at least twice the length (l_1) of the cylindrical portion. The tapered portion leads into a second cylindrical portion the length (l_3) of which is at least twice the length (l_1) of the first cylindrical portion. The cyclone may be used in a pressure vessel (11) in which any oil which flows through the underflow outlet of the hydrocyclone is allowed to settle under gravity within an underflow chamber (14) of the pressure vessel for removal separately from the water.

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HYDROCYCLONE SEPARATOR

The present invention relates to a hydrocyclone separator for separating a liquid mixture into a less dense component and a more dense component. The invention is particularly suitable for separating an oil/water mixture in which oil is the continuous phase and water is the dispersed phase. Such a hydrocyclone is known in the art as a dehydrating hydrocyclone.

In known dehydrating hydrocyclones, such as those disclosed in EP-A-259104 and EP-A-368849, the hydrocyclones have a separating chamber which, at the end adjacent to the inlet, has a short substantially cylindrical portion, followed by a first steeply tapering portion and a second less steeply tapering portion. The length of the cylindrical portion is short, so that the flow through the hydrocyclone quickly encounters the steeply tapering portion and is accelerated.

The dehydrating hydrocyclones operate effectively in as much as, for a given inlet oil concentration, a stream having a desired oil concentration can be obtained at the overflow outlet. However, this is done at the expense of the underflow outlet stream which represents an undesirably large proportion of the total flow, has a high oil concentration, and is still an oil continuous stream.

According to a first aspect of the present invention there is provided a hydrocyclone separator for separating a liquid mixture into a less dense component and a more dense component; the hydrocyclone having a wall defining an axially elongate separation chamber in the form of a surface of rotation, a liquid mixture inlet at one end of the chamber and which is arranged to cause the liquid mixture entering the separating chamber through the inlet to swirl about and progress along the axis, an overflow outlet at the one end for the less dense component, and an underflow outlet at the other end for the more dense component, the separation chamber comprising a first

substantially cylindrical portion extending axially from the one end towards the other end, and a tapered portion extending axially from the first substantially cylindrical portion towards the other end, wherein the length of the first cylindrical portion is at least twice its diameter.

Providing such a long cylindrical portion was previously believed to be undesirable as it leads to a deceleration of the flow. However, it has now been found that, contrary to expectations, such an arrangement actually improves the separation efficiency. The length of the cylindrical portion is preferably at least three times its diameter.

As the invention provides a more efficient separation, the same overflow oil concentration can be achieved at a lower underflow rate, so that the underflow stream represents a smaller proportion of the total flow and has a smaller concentration of oil, which can be made sufficiently small that the underflow stream is water continuous. This has advantages for subsequent separation of the underflow stream.

It is preferred that, within reason, the cylindrical portion should be as long as possible, and preferably the length of the first cylindrical portion should be at least n times the diameter of the first cylindrical portion, where n is any one of the integers from 3 to 20.

Preferably, the diameter of the first cylindrical portion is between 2.5 and 5 times the overflow outlet diameter, and is more preferably substantially 4 times the overflow outlet diameter.

Preferably, the length of the tapered portion is at least twice the length of the first substantially cylindrical portion.

Preferably, the included angle of the tapered portion is between 4° and 8°, and is more preferably substantially 6°.

In addition, separation can be improved if the separation chamber further comprises a second substantially

cylindrical portion extending from the tapered portion to the other end. The length of the second substantially cylindrical portion is preferably at least m times the diameter of the first cylindrical portion wherein m is any one of the integers from 2 to 20.

In order to improve the capacity of the hydrocyclone for a given size, the end wall at the one end is preferably inclined so that as the mixture from the inlet swirls about the axis of the chamber, the end wall imparts to the mixture an axial component of momentum in a direction towards the other end. Preferably, the end wall is substantially in the form of a helix which gradually extends axially towards the other end as the circumferential distance away from the inlet, or a respective inlet where more than one inlet is used, in the direction of swirl of the mixture increases and terminates in a step adjacent to the inlet, or the next inlet in the direction of swirl of the mixture where more than one inlet is used. This arrangement is the subject of co-pending British application GB 9516381.2.

In order to improve the quality of the overflow outlet stream, a core finder is preferably provided at the overflow outlet. This takes the form of a short tube extending axially from the overflow outlet into the separation chamber by a distance at least axially beyond the liquid mixture inlet, but not more than twice the axial length of the liquid mixture inlet.

The hydrocyclone separator in accordance with the invention has a particular application in a method of separating an oil/water mixture in which oil is the continuous phase, and water is the dispersed phase. The water content may be up to 20% by volume. In such a method, the mixture is introduced into the hydrocyclone inlet, and is separated into an oil enriched stream at the overflow outlet, and an oil depleted stream at the underflow outlet. Preferably, the oil depleted stream at the underflow outlet is water continuous.

According to a second aspect of the present invention there is provided an oil/water separation apparatus comprising a pressure vessel which is divided into an inlet chamber, an overflow outlet chamber and an underflow outlet chamber, the inlet chamber being provided with an inlet for an oil/water mixture, and at least one hydrocylcone, capable of separating a mixture of liquids into a more dense and a less dense component, with an inlet open to the inlet chamber, an overflow outlet for the less dense component and discharging into the overflow chamber, and an underflow outlet for the more dense component and discharging into the underflow chamber, the overflow chamber being provided with an oil outlet, and the underflow outlet chamber being provided with a water outlet and an oil outlet elevationally above the water outlet.

This apparatus provides what amounts to a two phase gravity separator for the liquid discharged from the underflow of the hydrocyclone(s). The apparatus is particularly useful when the or each hydrocyclone is a dehydrating hydrocyclone, as although the overflow stream is relatively pure oil, the underflow stream still contains a high proportion of oil. The apparatus is particularly successful when the or each hydrocyclone is a hydrocyclone separator according to the first aspect of the present invention, as the underflow from such hydrocyclone is coalesced and separates rapidly in the underflow chamber.

In order to promote phase separation in the underflow chamber, a baffle system is preferably provided in the upper part of the underflow chamber.

An example of a hydrocyclone separator constructed in accordance with the present invention will now be described with reference to the accompanying drawings, in which:

Fig. 1 is a schematic axial section of the hydrocyclone according to a first aspect of the present invention;

Fig. 2 is an enlarged section taken along line II-II in Fig. 1;

Fig. 3 is a section taken along line III-III in Fig. 2; and

Fig. 4 is a schematic drawing of the apparatus according to a second aspect of the present invention.

The hydrocyclone separator has a wall 1 defining a separation chamber 2. At one end of the separation chamber 2 are a pair of inlets 3 disposed symmetrically about the axis 4 of the hydrocyclone. As can be seen in Fig. 2 the inlets 3 are tangential to a circle centred on the axis 4, so that the liquid mixture entering the hydrocyclone is caused to swirl about the axis 4. The inlets, when viewed in the axial direction, converge towards the separation chamber at an angle of substantially 15° as shown in Fig. 2. The wall of the hydrocyclone adjacent to the inlet end is provided with two ramped surfaces 5 which are configured so that the liquid mixture entering the hydrocyclone is given an axial component of momentum by the surfaces 5 as it swirls about the axis 4.

An overflow outlet 6, having a diameter d_0, is provided at the same end as the inlets 3, and an underflow outlet 7 is provided at the opposite end of the separation chamber 2.

The separation chamber is generally made up of three separate portions. The first portion is a cylindrical portion 8 of length l_1 and diameter d_1 which extends from the inlet end towards the opposite end. The cylindrical portion 8 extends without a discontinuity into a tapered portion 9 of length l_2 and having an included taper angle of θ. The tapered portion 8, in turn, extends without a discontinuity into a second cylindrical portion 10 of length l_3 and diameter d_3. Typical values for these parameters are as follows:

l_1 = 152mm

d_1 = 40mm

d_0 = 10mm

l_2 = 325mm

θ = 6°

l_3 = 250mm

d_3 = 6mm.

The separation apparatus shown in Fig. 4 comprises a pressure vessel 11 divided into an inlet chamber 12, an overflow chamber 13, and an underflow chamber 14 by a pair of plates 15. The inlet chamber 12 has a liquid mixture inlet 16 and a plurality of hydrocyclones 17, which are preferably in accordance with the first aspect of the present invention. The hydrocyclones 17 are held in place between the two plates 15 so that each hydrocyclone has its inlet open to the inlet chamber 12, its overflow outlet open to the overflow chamber 13, and its underflow outlet open to the underflow chamber 14.

An oil outlet 18 leads from the overflow chamber 13, and an optional pump 19 is provided to remove the oil. A second oil outlet 20 leads from the upper part of the underflow chamber 14 and is combined with the flow from the oil outlet 18. The flow of oil from the underflow chamber 14 is controlled, for example, by a differential pressure controller 21 in order to maintain the overall hydrocyclone split ratio at the desired level.

The water which settles at the bottom of the underflow chamber 14 is removed via a water outlet 22. The water flow is controlled, for example, by a valve 23 which responds to signals from an interface level control 24 to maintain the level of the oil/water interface in the underflow chamber 14 at a desired level.

A system of internal baffles 25 can be provided in the upper part of the underflow chamber 14 to promote phase separation.

CLAIMS

1. A dehydrating hydrocyclone separator for separating an oil/water mixture into a less dense oil enriched phase and a more dense oil depleted phase; the hydrocyclone having a wall (1) defining an axially elongate separation chamber (2) in the form of a surface of rotation, a liquid mixture inlet (3) at one end of the chamber and which is arranged to cause the liquid mixture entering the separating chamber through the inlet to swirl about and progress along the axis (4), an overflow outlet (6) at the one end for the less dense component, and an underflow outlet (7) at the other end for the more dense component, the separation chamber comprising an elongate first substantially cylindrical portion (8) extending axially from the one end towards the other end, and a tapered portion extending axially from the first substantially cylindrical portion (9) towards the other end, wherein the length (l_1) of the first cylindrical portion is at least twice its diameter (d_1).

2. A separator according to claim 1, wherein the length (l_1) of the cylindrical portion (8) is at least three times its diameter (d_1).

3. A separator according to claim 1, wherein the diameter (d_1) of the first cylindrical portion (8) is between 2.5 and 5 times the overflow outlet diameter (d_0).

4. A separator according to claim 1, wherein the length (l_2) of the tapered portion (9) is at least twice the length (l_1) of the first substantially cylindrical portion (8).

5. A separator according to claim 1, wherein the included angle (8) of the tapered portion is between 4° and 8°.

6. A separator according to claim 1, wherein the separation chamber (2) further comprises a second substantially cylindrical portion (10) extending from the tapered portion (9) to the other end.

7. A separator according to claim 1, wherein the face of the end wall (5) at the one end is configured that as the mixture from the inlet swirls about the axis (4) of the chamber, the end wall imparts to the mixture an axial component of momentum in a direction towards the other end.

8. A separator according to claim 1, wherein a core finder is provided at the overflow outlet (6) comprising a short tube extending axially from the overflow outlet into the separation chamber by a distance at least axially beyond the liquid mixture inlet (6), but not more than twice the axial length of the liquid mixture inlet.

9. An oil/water separation apparatus comprising a pressure vessel (11) which is divided into an inlet chamber (12), an overflow outlet chamber (13) and an underflow outlet chamber (14), the inlet chamber being provided with an inlet (16) for an oil/water mixture, and at least one hydrocylcone (17), capable of separating a mixture of liquids into a more dense and a less dense component, with an inlet open to the inlet chamber, an overflow outlet for the less dense component and discharging into the overflow chamber, and an underflow outlet for the more dense component and discharging into the underflow chamber, the overflow chamber being provided with an oil outlet (18), and the underflow outlet chamber being provided with a water outlet (22) and an oil outlet (20) elevationally above the water outlet.

10. An apparatus according to claim 9, wherein a baffle system (25) is provided in the upper part of the underflow chamber (14).

Fig.1.

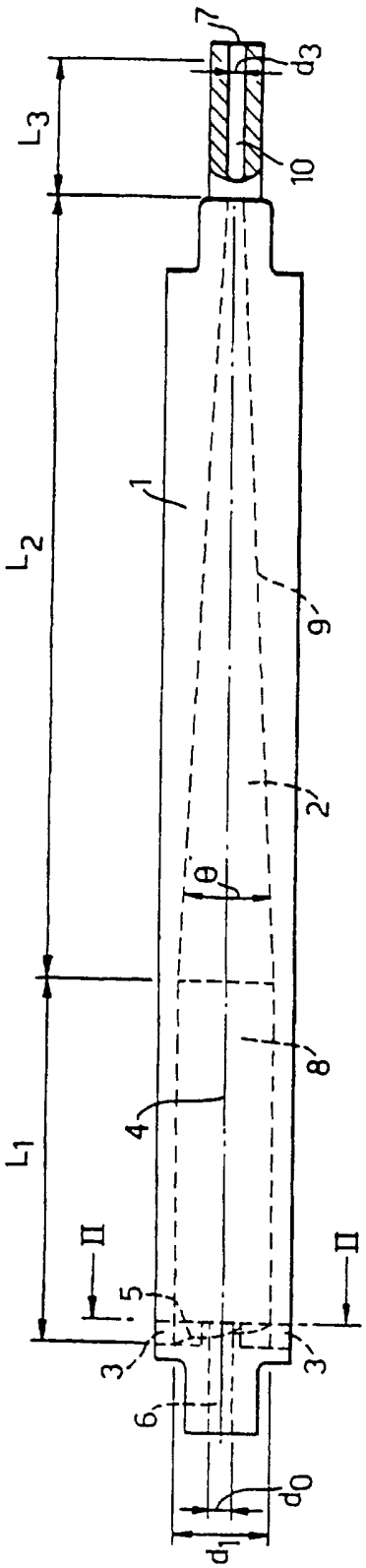


Fig.3.

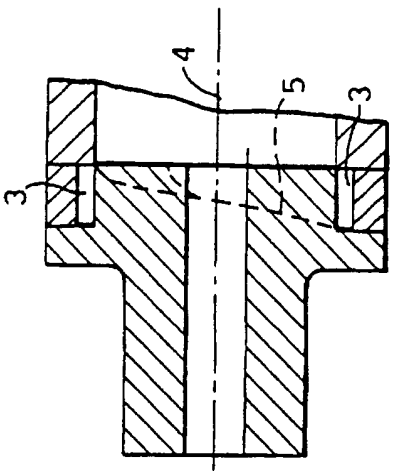


Fig.2.

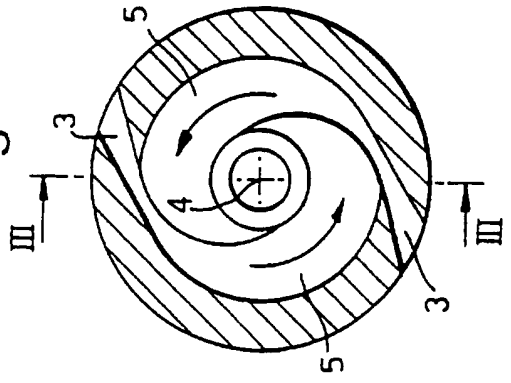
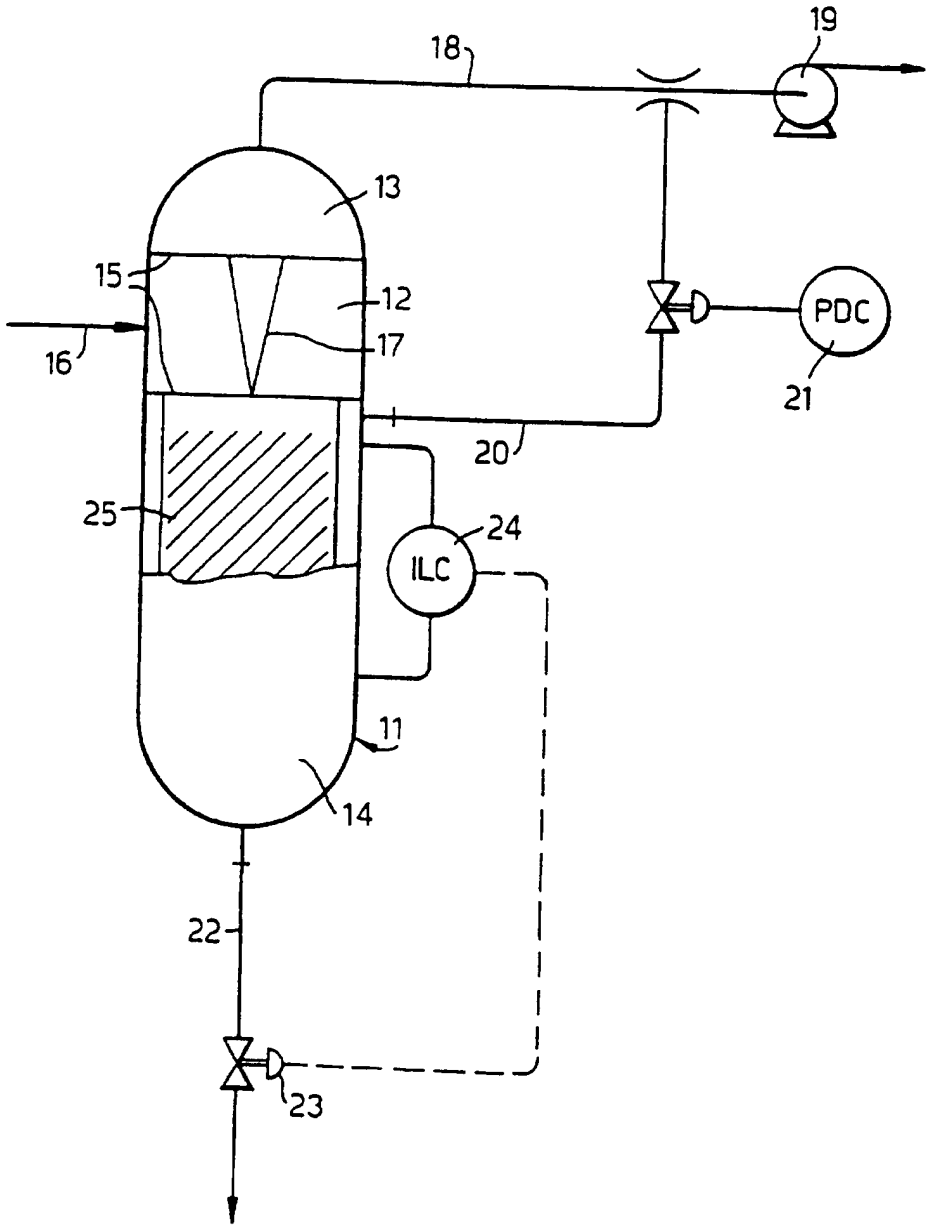


Fig.4.



INTERNATIONAL SEARCH REPORT

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A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 B04C5/081 B04C9/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 B04C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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Y	---	3,7
Y	WO 89 08503 A (CONOCO SPECIALTY PRODUCTS INC.) 21 September 1989 see page 5, line 15 - page 9, line 1; figures	3
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[X] Further documents are listed in the continuation of box C.

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Date of the actual completion of the international search	Date of mailing of the international search report
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